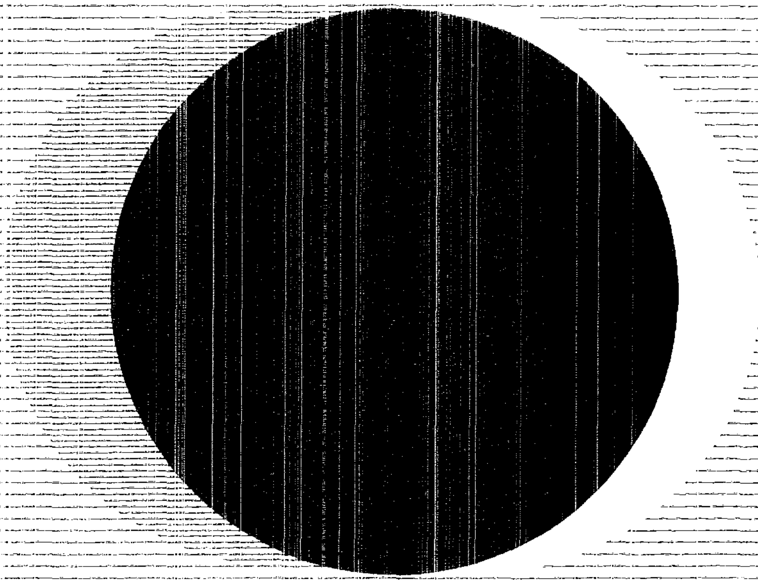
THE ATOM

Los Alamos Scientific Laboratory April, 1965



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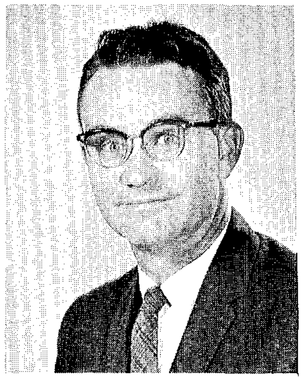
ON THE COVER:
As it has done frequently in the past, THE ATOM called upon LASL illustrator Hal Olsen to provide the cover for this month's issue. Olsen's ability to combine art and science resulted in this abstract work suggesting a solar eclipse. Why a solar eclipse is of interest to the Laboratory is explained in an article beginning on page 10.

Short Subjects

The year 1973 is the earliest "realistic" date for a flight test of the first U.S. nuclear-propelled rocket, Harold Finger, Manager of the Space Nuclear Propulsion Office, told the Senate Space Committee last month. He estimated it would cost one billion dollars to get it aloft. The figure would include construction of the vehicle and design and construction of facilities for the test. Finger said the plan is to use a cluster of LASL-developed Phoebus reactors to power the rocket.

SUNDBERG



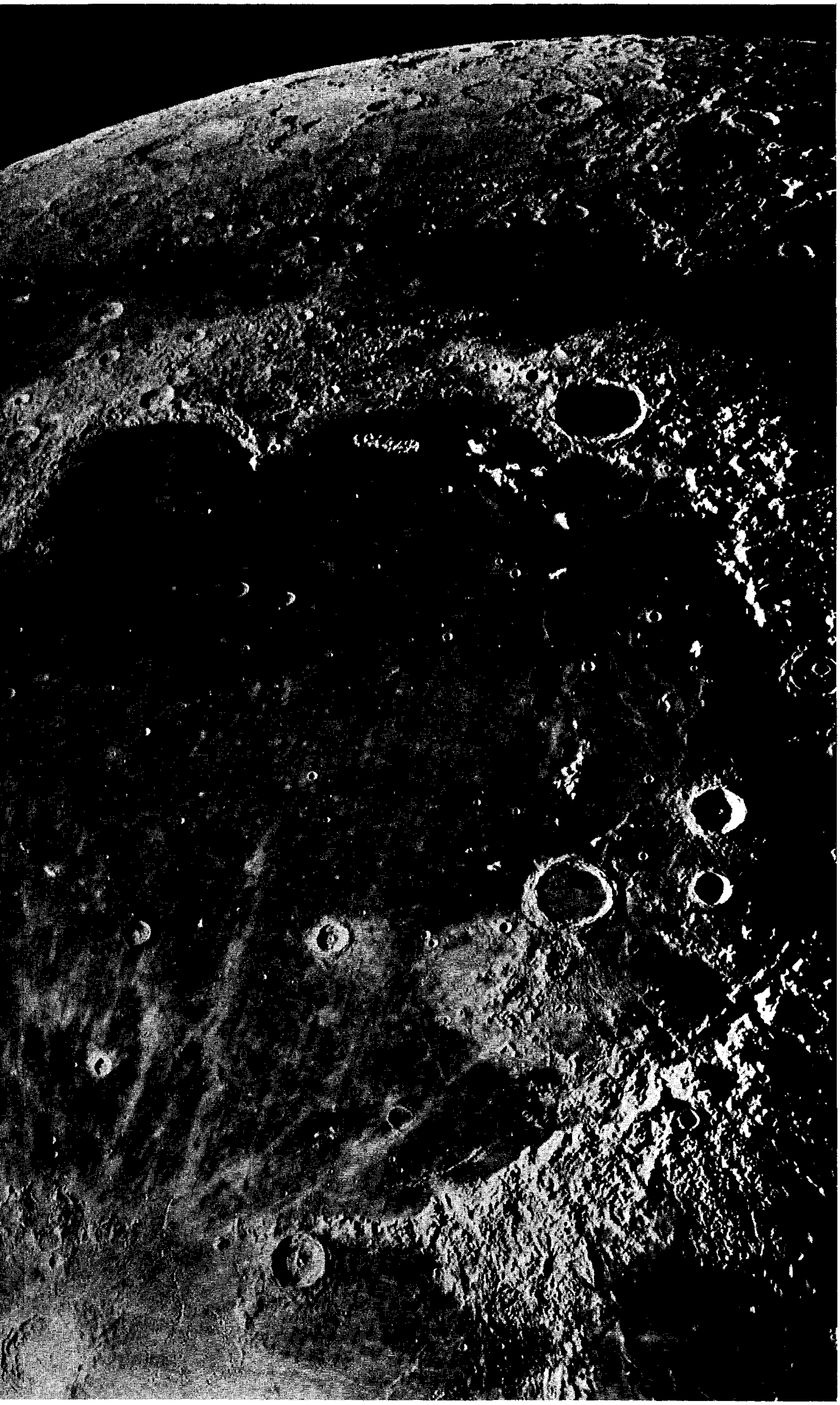
ZIMMERMAN

Wright H. Langham, H-4 group leader, served as editor-in-chief of a special issue of Aerospace Medicine magazine distributed last month. The issue is a "special report" devoted to discussions of radiation biology and space environment and how counterradiation measures affect manned spacecraft design and operation. The publication project was jointly sponsored by LASL and the McDonnell Aircraft Corporation of St. Louis, Missouri. In addition to Langham, contributors from LASL included Elizabeth Sullivan, Phillip Dean, Ernest Anderson, W. R. Gibbs and Valerie Gibbs.

David Sundberg, a member of the Public Relations Department staff since 1961 and editor of THE ATOM, has been appointed editor of Nuclear News, monthly magazine of the American Nuclear Society. He and his family moved March 26 to Hinsdale, Illinois, where the ANS is headquartered. Replacing Sundberg on THE ATOM is Earl Zimmerman, a former Omaha, Nebraska, newsman and PUB staffer since 1962.

James L. Tuck, head of the LASL Sherwood Project, will serve as a visiting lecturer at Colorado College, Colorado Springs, April 7 through 9. His visit will be under the auspices of the American Association of Physics Teachers and the American Institute of Physics as part of a nationwide program to stimulate interest in physics. Tuck will give lectures, hold informal meetings with students, and assist faculty members with curriculum and research problems.

The AEC has advised contractors it will invite bids, about April 5, for rehabilitation of the electrical distribution system in the Los Alamos community. Estimated cost range is $350,000 to $400,000. Work will include rebuilding some existing lines, erecting new poles and installing a variety of underground equipment. The job is to be completed within 270 days after the successful bidder receives notice to proceed. Bids are tentatively scheduled to be opened April 29.



Nevada Test

Moon-Like Training

A dozen American astronauts visited the Nevada Test Site recently to get an idea of the kind of terrain they may find on the moon.

The sprawling Test Site contains numerous craters, both volcanic and man-made, resembling meteoritic impact craters that cover the lunar surface. The Test Site also contains several large calderas, or crater areas from ancient volcanic activity which may be found on the moon.

The astronauts came to the test site in three groups, each about a week apart, in late February and early March. They were briefed by staff members of the U.S. Geological Survey who accompanied them on their tours.

Craters of the Moon

Copernicus Crater is seen at the bottom left in this photograph by Mount Wilson and Palomar Observatories.

Site Craters

Area for Astronauts

Among areas they inspected during their three-day visit was Yucca Flat, where nuclear explosive tests have been conducted since the early 1950's. There they inspected a number of explosion-produced craters, including the giant Sedan crater, created in 1962.

At one of the Site's "forward areas" small dynamite blasts were set off to allow the astronauts to practice geophysical observations using seismic equipment.

Later, the future spacemen visited the Nuclear Rocket Development Station, where LASL and other organizations are developing nuclear reactors for rocket propulsion.

Craters of the N T S

Sedan, and other man-made craters seen in an aerial photograph by LRL-Nevada.

Amazing Discovery!

Extremely Rare Animal—the Bilk—Found Near Los Alamos

Cross-country skiers and snowshoers who have ventured over the rim of the Valle Grande west of Los Alamos report having seen on several occasions a herd of very large grazing animals tentatively identified as the extremely rare bilk, a cross between a bison and an elk.

Deep snow drifts blocking the roads have made it impossible to get close enough by automobile to make an inspection, and parties on foot who attempted to approach the herd report the huge animals fled on sight of humans. Through high-powered binoculars, however, members of the Los Alamos Ski Patrol have been able to make a fairly positive identification.

While bearing a close resemblance to the buffalo, the bilk nevertheless has several characteristic features of the elk, such as its tremendous antlers, conspicuous by their absence from several miles distance with the naked eye.

Members of the Ski Patrol were able to get photographs of the hoof prints of the beast which are different in shape from those of the elk or the bison and are considerably larger. The powerful front cutting edge, shaped like a notched crescent, is used to paw through deep snow for grass, accounting for the herd's ability to survive the heaviest winters. One photograph was made of two of the animals by means of an extremely powerful wide-angle telephoto lens.

Very few occurrences of the hybrid bilk, also known as an elson, have been reported previously, although cross-breeding between different species of large hoofed animals is very common—for example, the mule is a cross between a horse and a donkey, and the cattalo a cross between domestic cattle and the buffalo.

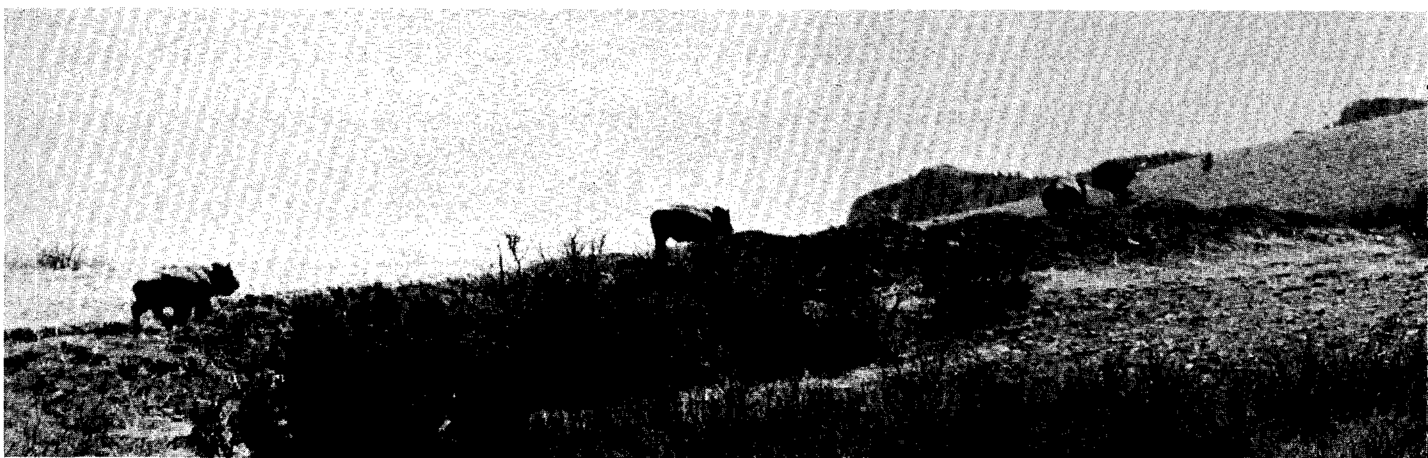
While the Valle Grande bilk herd may be the largest ever discovered, the first recorded evidence of the animal's existence pre-dates history. The ancient Greeks called it by its Latin name, *usu hirsutus abominabalus.*

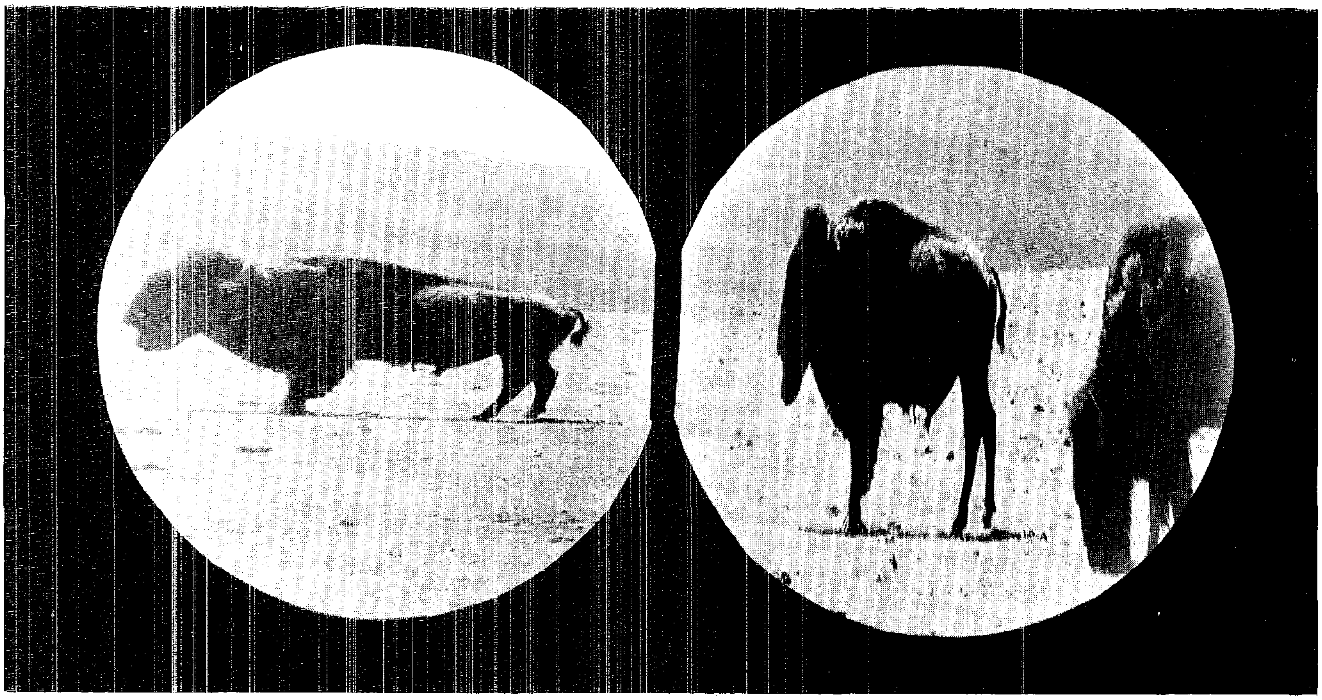
Famed Early American fur trapper and explorer Jim Bridger encountered at least a small herd of bilk during one of his frequent camping trips in Yellowstone National Park. Unfortunately, Jim had acquired a reputation as a liar due to some of his previous stories about geysers that abound in that area. Feeling he wouldn't be believed anyway, he never bothered to tell anybody. We wouldn't know it ourselves had it not been for one lone entry in his journal: "the bigist dam elafints i iver sawed."

Unconfirmed reports from the north, apparently based on Eskimo hunting experiences, say the bilk runs to about a ton in weight, and is about ten feet long. They are shaggy and ugly and mean as anything.

The exact circumstances which the bison-elk cross could have occurred in the Valle Grande is not known. Elk have been re-estab-

Rare photograph of bilk trotting over a ridge near Los Alamos.





Close-up view of bilk seen through binoculars shows their characteristic shape. The bilk is a cross between bison, elk.

lished there for more than 20 years, under protection, after having been hunted to extinction before the turn of the century. But local game experts were at a loss to account for the presence of buffalo in the Valle Grande unless they were deliberately imported, perhaps from the captive herd at Taos Pueblo, or a larger one in the Cimarron.

Owners of the Valle Grande, who previously have admitted to some ambitious plans for development of their 100,000-acre Baca Ranch for recreation, were unavailable for comment, having gone back to Texas for the winter.

One persistent report locally is that a former AEC official here, since transferred to Washington, made a trade with the Taos Indians, acquiring several pairs of buffalo in exchange for some mule deer. Mule deer have become so abundant in the county they have to be trapped periodically and taken away because they were in danger of starvation from over-grazing. The Taos buffalo, intended for a zoo, apparently escaped and went over the hill to the Valle Grande. The incident escaped public attention at the time and had been forgotten until the reports of the hybrid herd aroused the recollection.

Since this alleged swap occurred eight or ten years ago, before the present owners of the Valle Grande acquired the ranch, it is possible they also were not aware of the existence of the herd.

The fact that there is no longer any large-scale grazing in the Valle Grande, for the first time in 75 years, may contribute to the fact that the herd is being seen. Without the competition from cattle and sheep, the bilk herd may expand rapidly in the lush, grassy meadows of the great volcanic crater. There are few predators left in the Jemez Mountains; possibly none that would want to tangle with these huge beasts.

Unlike mules, the hybrid bilk apparently are not sterile. Several half-grown calves were seen with the herd, leading to the assumption they were born in winter, perhaps in the warm air region around the steam wells and hot springs on the western side of the crater.

State game officials report a flood of questions about hunting licenses for the bilk, and as to whether there would be an open season. All the Valle Grande is private property, and unless the animals stray into the national forest areas surrounding the crater, they may not be hunted at all without permission of the owners.

Part of the adjacent land is on various Indian pueblo holdings, suggesting the possibility the Indians may find the bilk a handy source of meat. Indian lore has it that the bilk was introduced into the Southwest by the Spanish conquistadores, who used them in battle much as tanks are used in modern warfare. The Spanish would stampede the bilks in the direction of the Indian defenses, following up with waves of foot soldiers. The bilks, their tough skins impervious to the Indians' spears and arrows, would crash into defenders who refused to retreat.

So terrible were the raids that, to this day, Indians still talk of being bilked by the white man.

Scenery Below Sea

Death Valley Via Titus Canyon

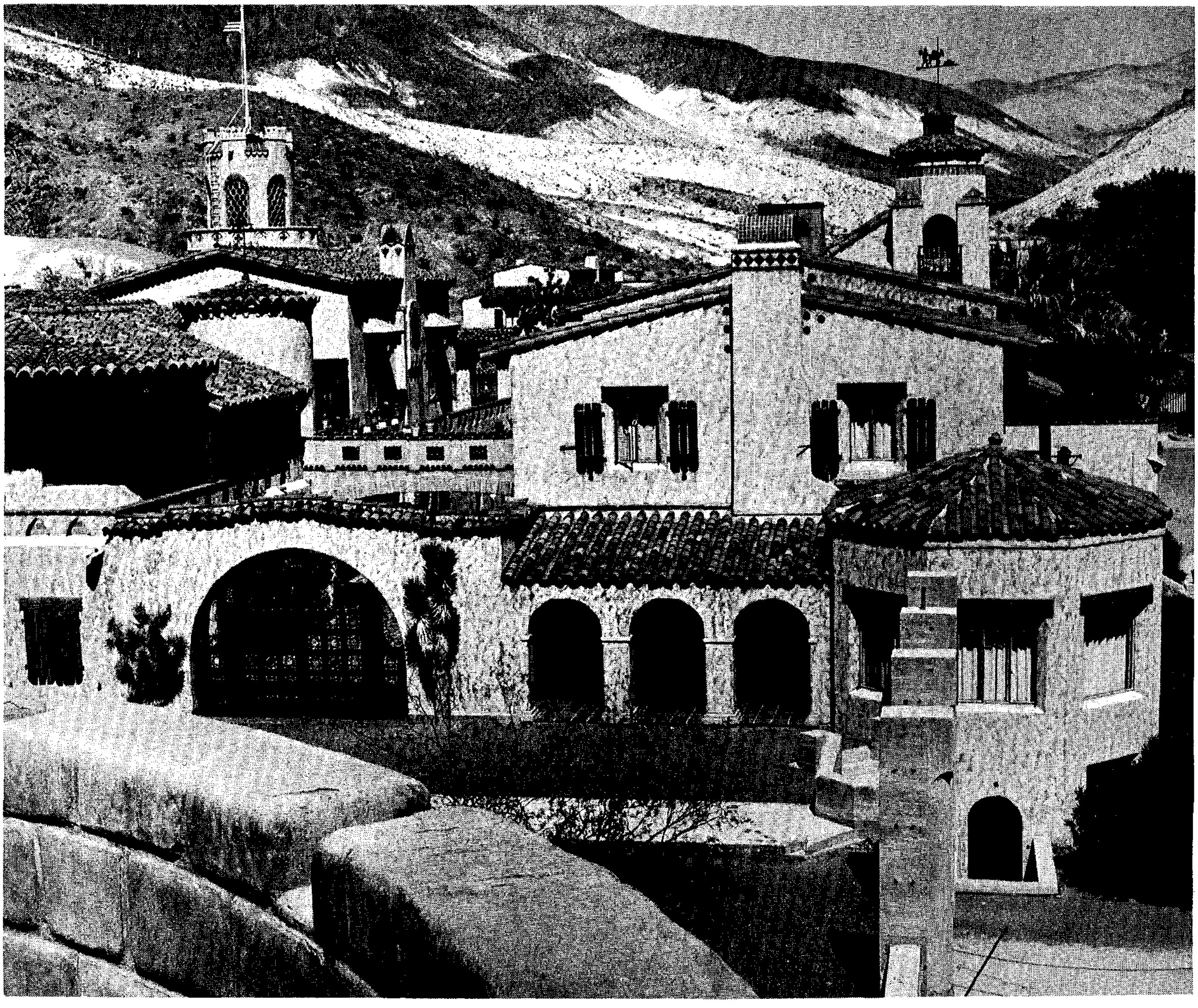
BY PETER MYGATT

An outstanding weekend or single day trip for those staying at NTS/NRDS or for those living in Las Vegas is a tour of Death Valley via Titus Canyon.

The ideal way to make the trip is to leave early in the morning, drive northwest on U.S. 95 to Beatty, Nevada (a good place for breakfast), then take Nevada State Road 58, stopping at the ghost town of Rhyolite just a few miles from Beatty.

The famous old railway station at Rhyolite, known as the "Dearborn Station of the West," is still

Scotty's Castle at the north end of Death Valley contains a restaurant and overnight facilities for the tourist.



Level

standing, and shells of other structures remain, along with mine tailings, to remind one of the past.

A few miles further on State Road 58 is an anomaly of the desert—a one way road hundreds of miles from the nearest major city. The sign blithely announces: Titus Canyon Entrance, One Way Road. The road takes off westwardly across a flat valley toward the Grapevine Mountains whose peaks rise from 6,000 to 8,000 feet above sea level. Seven miles west of these hills is Death Valley, and cutting through the Grapevines is a spectacular piece of Americana known at Titus Canyon.

And Titus Canyon is strictly one way—downgrade, steep, and narrow. But it can be negotiated by modern car from September to the end of May. The road follows the stream bed much of the way and the canyon walls tower hundreds of feet above; some of the time the canyon is so narrow it is almost impossible to open the car doors. Thus the canyon is closed from June through August since summer cloud bursts are a threat, and marks high on the canyon walls attest to just how much water the gorge carries during flash floods.

The scenery and colors of Titus Canyon are beautiful; the ghost mining camp of Leadfield will appeal to the frustrated desert rat; and there is Klare Spring with petroglyphs and pictographs—both ancient and modern.

Titus Canyon abruptly breaks out into Death Valley on a giant alluvial fan. The Valley was established as a National Monument in 1933, covering some 3,000 square miles. The monument is in the rugged desert region east of the Sierra Nevada in eastern California

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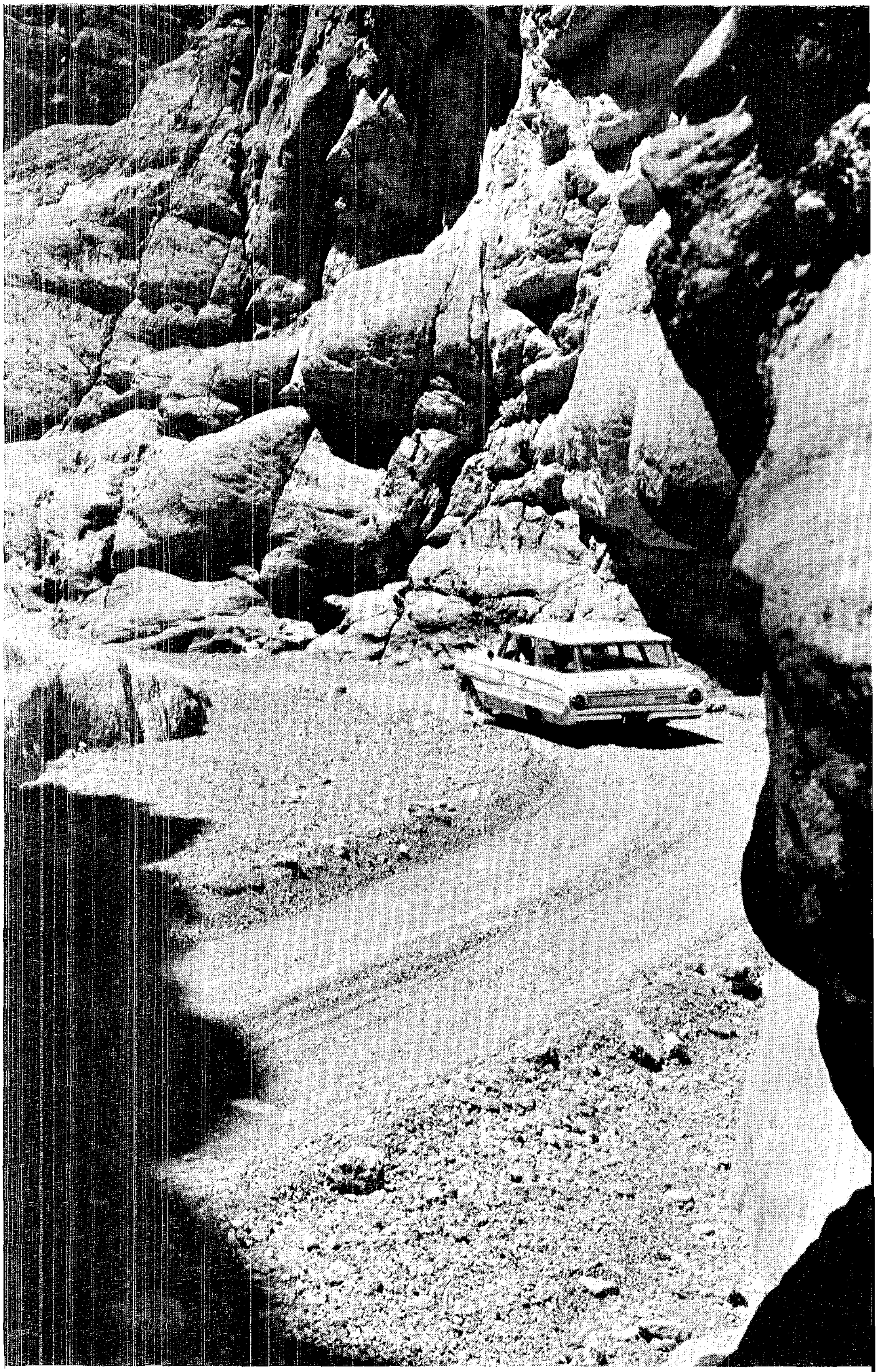
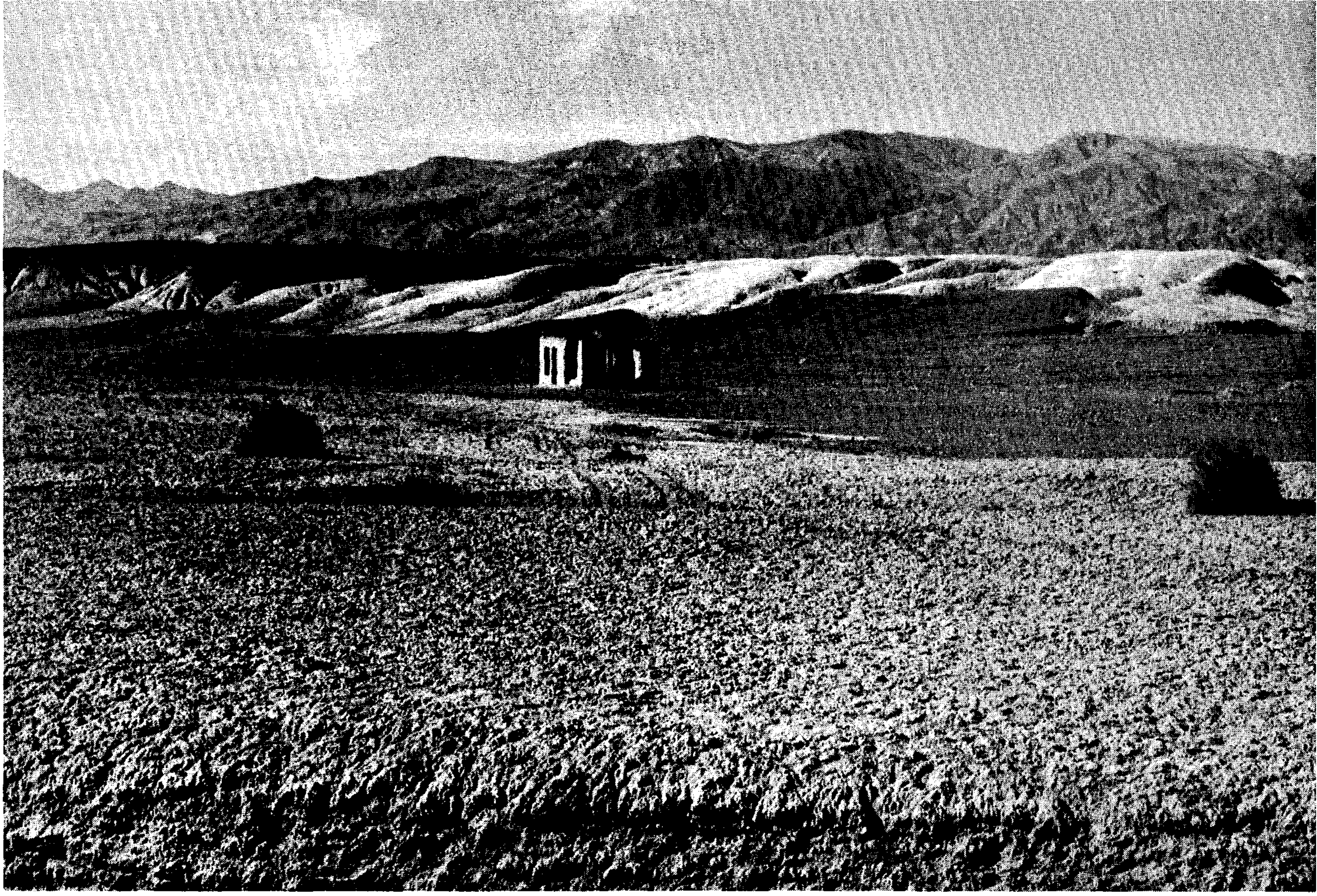


The river-bed road of Titus Canyon appears to vanish into solid cliff after solid cliff as it winds its way into Death Valley.



A lone adobe cabin sits in ruins near the Harmony Borax Works near Furnace Creek in Death Valley. In the distance are Panamint Mountains.

Titus Canyon . . .

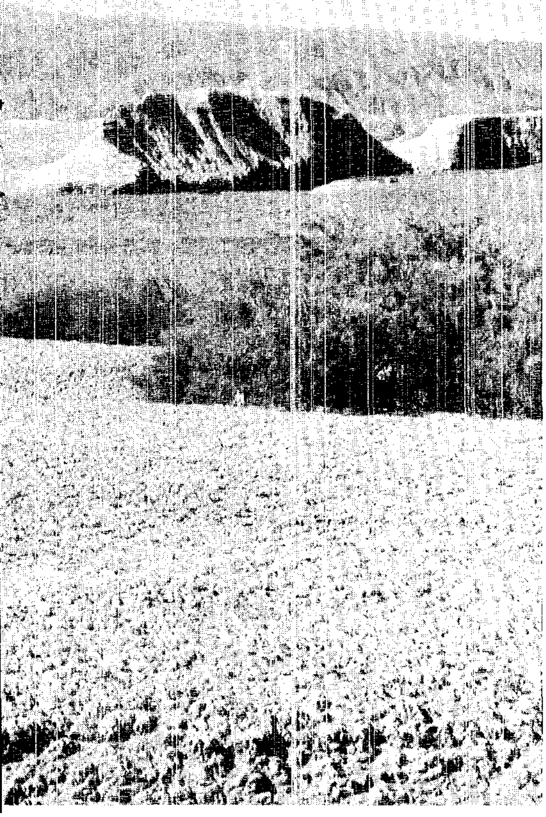
Rhyolite, once a booming mine town, is now just a skeleton in the desert.

continued from preceding page

and southwestern Nevada. The Valley itself is about 140 miles long, with the forbidding Panamint Range forming the western wall and the precipitous slopes of the Amargosa Range bounding it on the east. Running in a generally northwesterly direction, the Valley is narrow in comparison to its length, ranging in width from 4 to 16 miles. Nearly 550 square miles of the Valley are below sea level (a point near Bad Water is 282 feet below sea level, the lowest land in the Western Hemisphere). Telescope Peak immediately to the west towers 11,331 feet above the lowest point.

At the north end of Death Valley is the famed Scotty's Castle, and Ubehebe Crater; toward the center is the National Monument Visitor Center with its museum at Furnace Creek; while to the south are the ruins of the Eagle Borax Works, Bad Water, and the lowest point. And all along the route are numerous and worthwhile side trips.

There are a number of ways to exit from Death Valley, but the NTS/NRDS and Las Vegas tourists will find the best route is California State Road 190 which cuts off from Furnace Creek and ends at Death Valley Junction. From the Junction, one can drive due north on California 127 and Nevada 29 to Lathrop Wells, returning to the Test Site and Las Vegas via U.S. 95. An alternative route to Las Vegas is a dirt road which leaves Death Valley Junction and angles



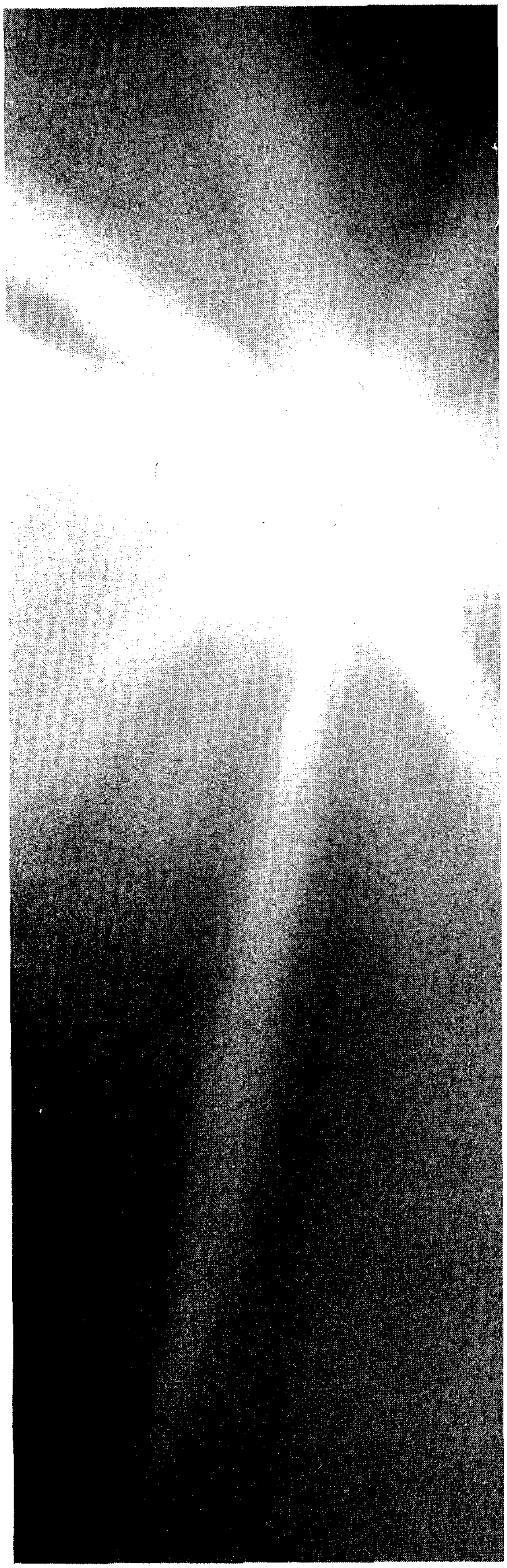
An old semaphore keeps a vigil over the Rhyolite, Nevada, railway station, not far from Beatty on U.S. Highway 95.

to the Nevada town of Pahrump, continuing down the Pahrump Valley to the Las Vegas-Los Angeles highway.

Death Valley National Monument is open year around, though the regular season is from about October 15 to May 15. However, one of the outstanding times of the year to make the trip is during March and April while the desert wild flowers are blooming.

Tommy Thompson, full of conversation, history, and humor, sells relics of bygone days at his home in Rhyolite.

Photograph by Bill Regan



Solar Eclipse eXpedition

BY EARL ZIMMERMAN

Two groups of LASL researchers will go to the South Seas next month to participate in experiments that have the fanciful title Operation SEX.

Relax—SEX stands for Solar Eclipse Expedition and the scientific sojourn in Polynesia will be as devoid of gender as a slice of wet bread.

While results of Operation SEX won't be publishable in the Kinsey Report, scientists hope they will fill gaps in man's knowledge about the sun. In effect, the experiments will take the sun's temperature and make other contributions to the International Quiet Sun Years, a two-year program of worldwide solar observations that extends through 1965.

LASL's role in the May 30 eclipse is two-part, involving people from J, P and CMF Divisions. Theirs and observations by a number of other research institutions are being coordinated by the National Science Foundation.

The eclipse, which will occur as the moon passes between the earth and the sun, will produce a night-like shadow that will sweep some 7,000 miles across mostly open sea, starting northeast of New Zealand and ending off the west coast of South America. "Totality" will not reach above the equator and the eclipse will be completely unseen in New Mexico.

Total eclipses are of special interest to scientists because they afford a unique opportunity to study the corona, a convulsive envelope

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SEX . . .

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of hot gas that surrounds the main body of the sun. It is coronal activity that plays a role in such earthly manifestations as the aurora and periodic radio transmission blackouts.

Since this is the last year for more than a decade that solar disturbances (for example, sunspots) will be at such a low level, the May eclipse is of particular interest to scientists the world over. Because of the remoteness of the eclipse path, elaborate and at times frustrating scientific and political preparations have been required to emplace instruments and people in positions where their observations will be of the greatest value.

One of the Los Alamos experiment series will use airborne instruments aboard LASL's diagnostic NC 135 jet aircraft. The other series will put instruments into the path of totality on Nike-Tomahawk rockets.

The flying laboratory will operate from American Samoa, flying out of Tafuna Airport at Pago Pago. The plane will chase the eclipse in the center of the shadow about 1000 miles east of Samoa and will be properly oriented for the critical observations for about 4½ minutes, according to Art Cox of J-15, who is in charge of the project. The shadow will be traveling easterly about 1,000 miles an hour, the aircraft about half that speed. The flight will be at about 35,000 feet altitude, above most of the clouds, water vapor and dust which traditionally have plagued solar eclipse observations.

Aloft in the plane will be Cox, William Ogle, Sid Stone, Ralph Partridge, Jim Hill, Walt Wolff, Paul Rudnick and Don Westervelt, all of J Division, Don Liebenberg and Ken Williamson of CMF-9, and Bill Regan of PUB. There will also be five "guest" scientists conducting experiments, three from Johns Hopkins University, one from the University of California at Los Angeles and one from the High Altitude Observatory of Boulder, Colo. Others aboard will include representatives of Sandia Corporation and Edgerton, Germeshausen and Grier, Inc., who will assist in operation of experiment equipment.

Chief interest of the aerial observers will be the determination of temperatures in the corona and densities and motions of the corona at a low-activity period. Experiments will include photographic and photoelectric measurements of the intensity, polarization, and emission line profiles of the coronal light, and "mapping" of the coronal spectrum with particular attention to the spectrum of highly ionized iron. These measurements will give clues to coronal temperatures, densities and the distribution of its magnetic field.

The rockets will be fired from portable land-based launchers on the island of Rarotonga. The launchers and rocket-to-ground telemetry equipment will be operated by crews from Sandia Corporation. Rarotonga is the capital island of the Cook Islands, possessions of New Zealand. The Los Alamos party will be headed by Harold Argo, alternate head of the Space Physics group (P-4) and will include James Bergey, Michael Montgomery, Sid Singer and Burton Henke, professor of physics at Pomona College and a LASL consultant. Doyle Evans is standing by as a P-4 alternate. Firing the rockets and running the electronics will be a seven-man launch and administrative crew from Sandia.

LASL's island station will be on a 135-acre coconut farm that has been leased from a retired sea captain. First equipment was shipped last month and the Sandia group was to start site preparation by the first of April.

There will be four launches during various phases of the two-hour eclipse phenomenon, Argo said. The two-stage rockets will send instrument payloads to an altitude of about 200 miles.

Purpose of these experiments is to make spectroscopic measurements of low-energy x ray emission lines that emanate from the corona. It has been difficult previously to determine the nature of the origin of these "soft" solar x rays, which lie in the spectral region between 16 and 45 Angstrom units. It is believed the emission lines come from atoms of carbon, nitrogen and oxygen that are highly ionized, that is—completely stripped of their electrons. Information in this energy range is of importance both for determining the coronal temperature and the elemental composition of the sun itself.

Spectrometers in the rockets will act as a sort of camera film and the moon will perform as the camera shutter. It is planned that as the "shutter" moves across the sun the sequential launchings will make it possible to establish the origin of the emission lines. One theory is that the energy comes from near the bottom of the corona, close to the sun's surface, and may be concentrated in localized solar disturbances. These so-called plage areas will be systematically obscured by the eclipse, making it possible to use the series of spectroscopic observations for pinpointing the location of the emissions.

Preparations for the two experiment series began nearly a year ago and were complicated by locating airfields adequate for the big NC 135 and a launch area that was within the range of the Nike-Tomahawk boosters.

The LASL plane will be one of four jets flown for U.S. scientists studying the eclipse. The others will carry scientists from Sandia Corporation, the National Aeronautics and Space Administration and the Air Force Cambridge Research Laboratory.

The LASL aerial observers are scheduled to leave Albuquerque for Samoa about May 21 and return about June 1. The Rarotonga detachment will leave Los Alamos about the first of May and return about June 8.

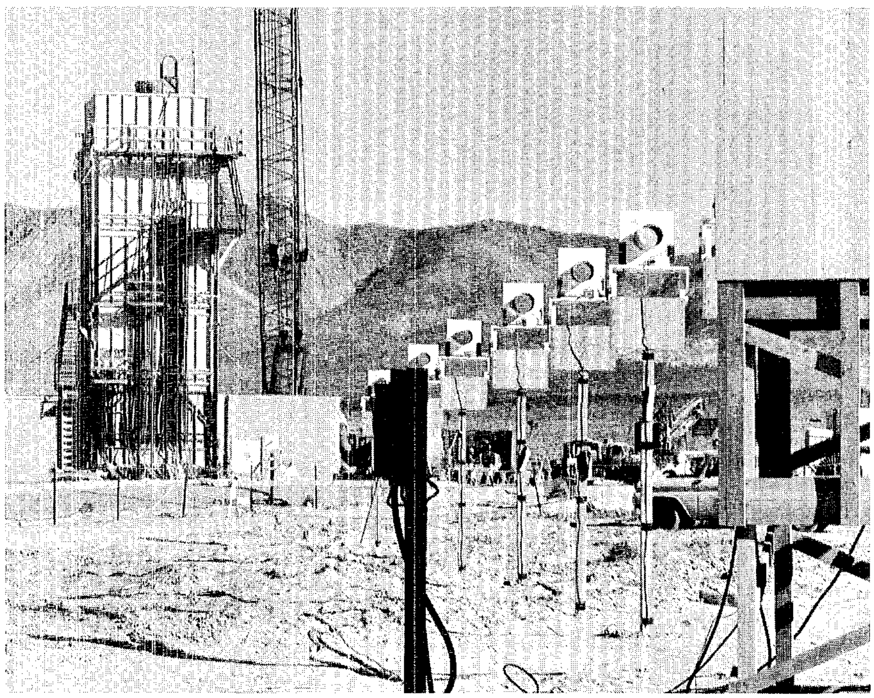
A Primer

ON MULTIPLE NEUTRON CAPTURE

Part II

By JOHN SAVAGE

A medieval alchemist would have been fascinated by what happened at Eniwetok in 1952. Uranium, a metal much heavier than gold, was transmuted into elements heavier still, including two elements never before known.
How was it done? What has been accomplished more recently in similar experiments? This primer, which began in last month's ATOM, is intended to answer those questions and to suggest what further progress is hoped for.



Mockup for an optical experiment, set up in preparation for a LASL underground nuclear weapon test.

Each atomic nucleus is a combination of nucleons (protons and neutrons). The more nucleons an atom contains, the heavier it will be.

Elements heavier than those occurring naturally on earth can be created artificially by the addition of nucleons to existing heavy nuclei. To accomplish such addition, target elements are bombarded with neutrons or protons or coherent clusters of the two. When a target nucleus captures and absorbs one or more of the additional nucleons, the result (while it lasts) is an abnormally heavy nucleus.

Such a nucleus will always be unstable. This means

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Primer . . .

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it will "decay" spontaneously, in a matter of seconds or of centuries, acquiring greater stability by making a corrective change in its own composition.

It it changes by fission (splitting in two) or by alpha particle emission (ejection of a helium nucleus), nothing remarkably heavy will remain. If, however, it changes by beta particle emission (ejection of one or more electrons), it may gain stability without losing much weight.

The way in which an unstable nucleus decays is dictated by the nature of its instability. If it is unstable because of an excess of neutrons per proton, it will usually decay by emitting a beta particle (an electron). The loss of this electron, with its negative charge, has the effect of putting a positive charge on one of the nuclear neutrons—transforming that neutron into a proton. If the nucleus is still too rich in neutrons, additional beta particles may be emitted, transforming other neutrons into protons. Each time an electron leaves the nucleus, the positive charge of the nucleus (the atomic number) goes up one unit. Beta emission will cease only when the proportion of neutrons to protons has been reduced to a point within the stability range. *By changing neutrons into protons, beta decay corrects a neutron surplus in the nucleus.*

Beta decay is often a sequel to neutron capture. When neutrons are used as projectiles to bombard a target, the target nuclei capture these projectiles and thus become heavier forms (neutron-rich isotopes) of the target element. These isotopes then decay, frequently by beta emission.

The sequence is observed at its simplest in the case of two hydrogen isotopes considered in the first half of this primer: Neutrons are used to bombard deuterium (hydrogen 2) targets. The target nucleus (one proton and one neutron) captures a second neutron and becomes tritium (one proton and two neutrons). Subsequent beta emission from the tritium nucleus transforms one of its two nuclear neutrons into a proton. The result is helium 3, a stable nucleus with two protons and one neutron. *Neutron capture raises the mass number (number of nucleons). Then beta decay raises the atomic number (number of protons). In these two steps, a portion of the target is transmuted into a heavier element.*

The hydrogen and helium of the foregoing example are very light elements. Fortunately, the sequence of neutron capture and beta decay works even better at the other end of the weight range. By using a heavy element as a target for neutrons, scientists produce still heavier elements. One good source of neutrons for heavy element production is a nuclear reactor. (The man-made element plutonium comes from reactors that were built for the specific purpose of making plutonium.) Another good source of neutrons is a nuclear explosion, because nuclear explosions liberate huge numbers of neutrons at extremely rapid rates.

Parts of the "Mike" thermonuclear device, detonated in 1952, were made of uranium metal. Most of the atoms in this metal were U^{238} (a uranium isotope containing 146 neutrons per nucleus and, like all uranium isotopes, 92 protons per nucleus). When the device was detonated, many of the neutrons liberated in the nuclear reaction were captured by nuclei of U^{238}. A few of the uranium nuclei may have captured no neutrons at all. Others captured one neutron each and became U^{239}. Still others captured many more neutrons each. An occasional uranium nucleus captured as many as 17 neutrons, forming U^{255}. This extremely heavy nucleus, being much too neutron-rich for stability, then emitted several electrons in succession. The mass number remained 255, since no nucleons (protons or neutrons) were ejected, but the number of protons (the atomic number) went up and the number of neutrons went down. Emission of the first electron changed the nucleus to neptunium 255 (element 93). The neptunium almost instantly emitted an electron to become plutonium 255 (element 94), and so on, until the neutron-proton ratio was brought into the range of greater stability. By the time the debris from the Mike shot was analyzed, it contained detectable amounts of element 99 and element 100, both at mass 255. Neither of these elements (since named einsteinium and fermium, respectively) had ever been observed in any form before. In addition to the two new elements (one of which, einsteinium, was detected at two different mass numbers), the Mike shot produced eleven new isotopes of elements previously known.

Two serious attempts to create heavy elements by using nuclear explosives were made during the first ten years after Mike. In the first of these, scientists from Los Alamos (where the Mike device had been created) were frustrated by the failure of a vital component of the experiment. That was in 1958. In the second of these (code-named Anacostia), scientists of the Lawrence Radiation Laboratory succeeded in creating heavy elements—but not to the same extent as Mike had done. That was in 1962.

Anacostia had two important features: (1) It was a fully-contained underground explosion, and (2) it was very little inferior to Mike as a neutron source, even though its total yield of explosive energy was a thousand times smaller. Both features were encouraging, for reasons requiring some discussion here.

Explosion of a nuclear device deep underground creates a bubble of hot gases under the surface of the earth. The bubble is lined with molten soil, and contains the explosion products. As soon as the vapors cool and condense, the cavity collapses. The explosion products, including any newly-created materials, are trapped in a concave layer at the position of the bottom of the original bubble. By skillful drilling, "cores" of fused soil can then be extracted from the concave layer for analysis. This kind of sampling after weapon tests was already standard procedure before the Anacostia event, but Anacostia was the first to make use of the method in connection with experimental creation of heavy elements.

The explosive force, or yield, of the Anacostia device was equal to that of a few thousand tons of TNT. The yield of the Mike device had been measured in megatons (millions of tons of TNT). Yet the Anacostia device was very nearly as intense a neutron source, for heavy element synthesis, as Mike. This showed that nuclear explosive devices for heavy element creation need not be large, if properly designed.

In October, 1964, at the Nevada Test Site, both the Lawrence Radiation Laboratory and the Los Alamos Scientific Laboratory conducted underground experiments designed to synthesize heavy nuclei by multiple neutron capture in U^{238} targets. The LRL experiment was code-named Par; the LASL experiment, Barbel. Both surpassed the intensity of Mike as a neutron source. Both duplicated the full range of heavy nuclides detected in the Mike debris, and both produced something heavier. This was fermium 257 (100 protons and 157 neutrons).

Fermium 257 now holds—or rather shares—the record. It is equal in mass number to the heaviest nuclide so far produced in this country. (Lawrencium 257, element 103, was made in Berkeley in 1961 by means of a particle accelerator called HILAC. Fermium 257 has been produced both by reactors and by explosions.) In the late summer of 1964, Russian physicists reported the creation, by bombardment with charged particles from an accelerator, of element 104 (still unnamed) at mass 260.

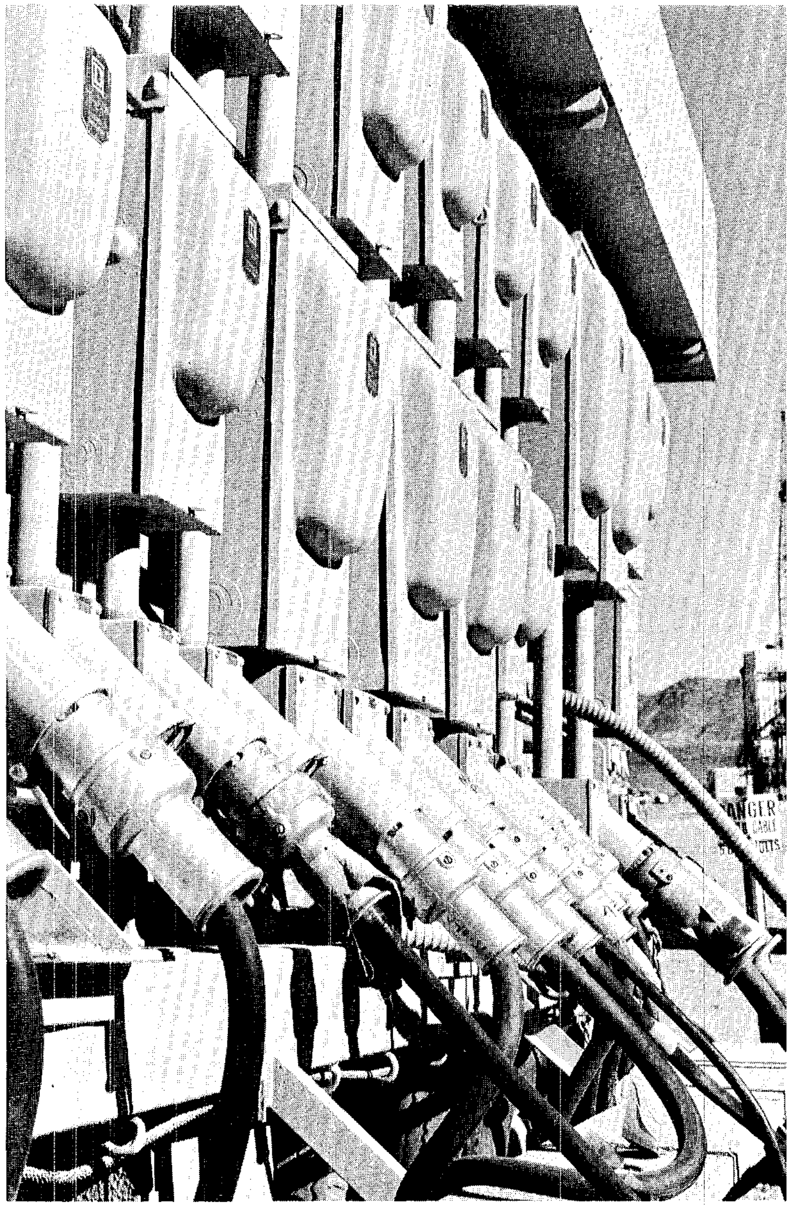
The mention of these facts brings up an important question: If reactors and particle accelerators can be used to make heavy elements, why should there be anything exciting about the use of nuclear explosives to do the same job?

The answer is that the job is not really the same. Each of the three kinds of tools performs a different task. Each has its own advantages and disadvantages, and its own specific area of usefulness. The true significance of current experiments with nuclear explosives can be understood only when the characteristics of the other tools are clear.

Particle accelerators (cyclotrons, Van de Graaffs, linear accelerators like HILAC, and so on) produce powerful beams of charged particles. The particles can be protons, helium nuclei, or even heavier combinations of nucleons. Such beams, when used to bombard heavy elements, create still heavier elements.

Among the advantages of particle accelerators for such work is the fact that a variety of particles can be used as projectiles. (The world's first samples of elements 101, 102, and 103 were created by accelerator bombardment of heavy targets with helium, carbon, and boron nuclei, respectively.) Other advantages of accelerators include the ease with which experimental conditions can be controlled and measured, and the ease of recovery of the entire target after the experiment.

Accelerators have disadvantages. Among these are the inability of particle accelerators to accelerate neutrons (since neutrons are uncharged and there-



Power switching apparatus for an underground nuclear weapon test.

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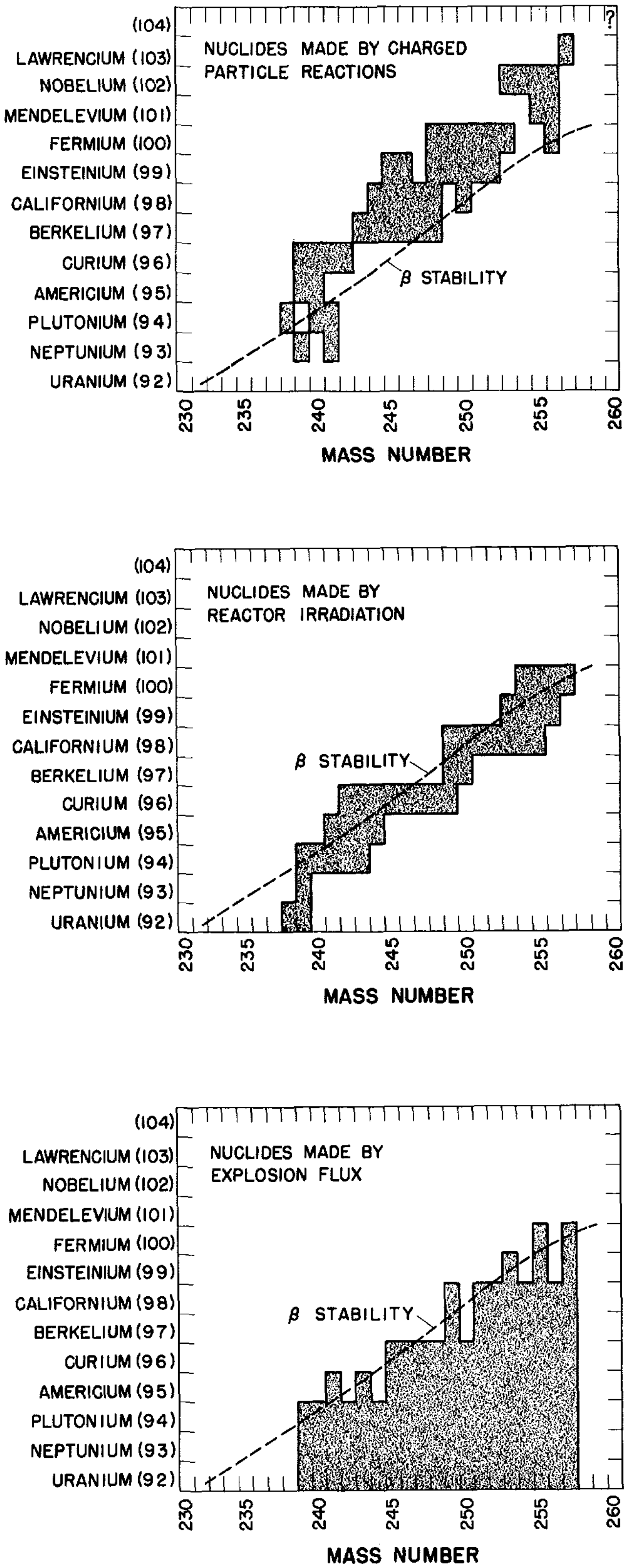


Synthetic nuclides made by each of the three research tools used in heavy element synthesis. See text for explanation.

Primer . . .

Continued from preceding page

fore unaffected by electrical accelerating forces) and the limited flux (number of particles passing through a given area per second) they can produce.

Nuclear fission reactors are good sources of neutrons and gamma rays. Neutrons from reactors have long been used in the production of heavy elements.

Reactors share some of the advantages of accelerators, such as the ease of making measurements and of recovering the sample. They cannot produce beams of charged particles, however, and their neutron flux, while very great, is much lower than that of a nuclear explosion.

Nuclear explosives have only one advantage: They produce much higher neutron fluxes than any other device in the world. Their numerous disadvantages (difficulty of recovering samples, for one) arise mainly from the inescapable fact that they cannot be exploded in a laboratory. Ways of minimizing these disadvantages have been found and are being improved, but the disadvantages are still there.

Though none of the three tools is "best" in every way, each is best in one way or another. As the figure on this page shows, each of the three does an essential job in the exploration of its own particular area of the unknown.

Accelerators, because they cannot directly produce a beam of neutrons, usually make heavy elements by adding charged particles (protons or proton-rich combinations) to nuclei. For that reason, accelerators are most useful in exploring an area on the proton-rich side of the line of beta stability.

Reactors are most useful in exploring an area *near* the line of beta stability. This is because reactors produce neutrons at a slower rate than nuclear explosions do. Reactors cannot work far from the beta stability line because a nuclide in the neutron flux of a reactor has time for beta decay, after capturing a neutron or two, before it captures another. Beta decay alternates with neutron capture as the nuclear mass increases.

Nuclear explosions produce such a huge flux of neutrons that multiple neutron capture occurs before there is time for beta decay. That is why nuclear explosions make it possible to reach very high mass numbers at relatively low atomic numbers—a distinct advantage, for reasons to be explained in a moment.

Just as each of the three tools is limited as to the area it can explore with respect to the beta stability line, each is almost certainly limited as to the weight of the heaviest nuclide it can produce. These limits have not yet been reached, but something can be surmised about them for each of the three cases.

Accelerators generally produce nuclides of high atomic number, poor in neutrons. Such nuclides often decay by spontaneous fission (splitting in two), and the likelihood of this kind of decay goes up as the mass increases. It appears possible, therefore, that any accelerator-produced nuclei much above the masses already attained may be destroyed by fission in too short a time to permit careful observation.

Reactors produce heavy nuclides that are poor neither in protons nor in neutrons. The limiting factor here arises from the fact (mentioned above) that reactors produce heavy nuclides rather slowly, working from one to the next, always near the beta stability line. It happens that at some points near that line nuclides exist which decay by fission or alpha particle emission. For example, fermium 256 (which decays rapidly by spontaneous fission) has been a formidable barrier to the effective production of much heavier nuclides by reactor neutrons. Other barriers at higher mass numbers may turn out to be insuperable.

Nuclear explosives work fast, because of their high neutron flux. This permits them to "go around" a barrier like Fm^{256}. They do so by producing mass numbers higher than 256 at atomic numbers below that of fermium, relying on subsequent beta decay to produce high atomic numbers.

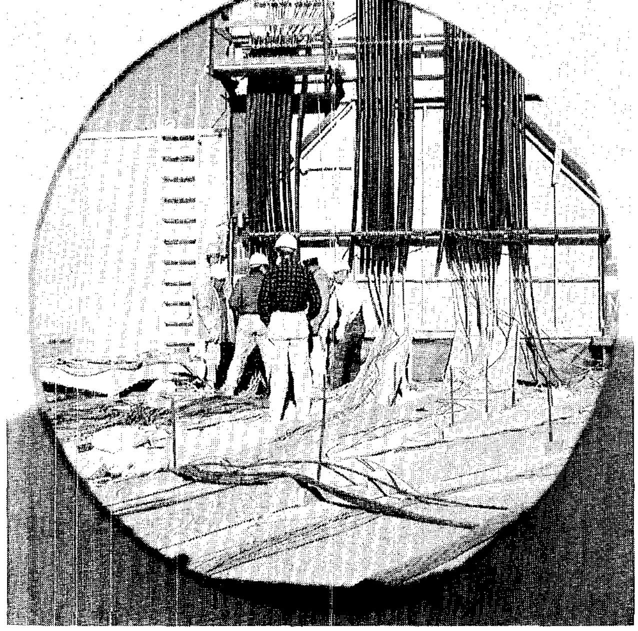
The multiple neutron capture process has limits too. For instance, as the neutron surplus in a given nucleus goes up, the willingness of that nucleus to accept additional neutrons goes down. The 19 successive neutron captures that turned U^{238} into U^{257} in the Par and Barbel experiments can be surpassed, but the number of such captures cannot be increased indefinitely.

Both reactors and explosives are useful for elucidating the processes of heavy element synthesis that occur in stars. Cosmologists believe there are two such processes, one slow and one rapid. In the "s" process (the slow one), elements are built up by neutron capture at rates slow enough to permit beta decay between captures—as in a reactor. In the "r" process (the rapid one), elements are built up by multiple neutron capture at rapid rates.

Nuclear explosives are the only research tool capable of producing multiple neutron capture at rapid rates.

What about the future of heavy element synthesis by means of nuclear explosions? Two advances are almost certain to be made in the next few months or years. One is the creation, by LRL and LASL, of explosive devices yielding a higher usable neutron flux than has been available so far. (Par and Barbel both exceeded Mike in that respect.) The other is the use of targets heavier than U^{238}. (This would make heavier products, even if the neutron flux—and the number of neutron captures—were not increased.)

In general, the higher the atomic number of a target nucleus is, the more neutrons that nucleus will accommodate during the neutron-capture phase



Preparations for an underground nuclear weapon test at the Nevada Test Site.

of heavy element synthesis. (There is good evidence that small quantities of neptunium, element 93, produced by charged-particle reactions during a nuclear explosion, function as a target for neutrons during subsequent stages of the explosion. One result of this is a slight increase in the ultimate yield of certain heavy nuclides.) The High Flux Isotope Reactor (HFIR), about to go into operation at Oak Ridge, will produce relatively large quantities of nuclides with atomic numbers higher than that of neptunium and with mass numbers from 245 to about 250. When such materials become available for use as targets, nuclear explosions will almost certainly produce heavier elements than they have created so far. And recent theoretical studies have provided a sound basis for believing that some of the super-heavy nuclides may be more stable than they were earlier thought to be.

Super-heavy elements are not at all likely to be produced in quantities useful for anything except scientific research. No one expects that they will change the world.

What they may change, however, is man's knowledge of the universe.

Why does the light of certain supernovae (exploding stars) fade out at exactly the rate it has been observed to do, taking about sixty days to diminish by fifty per cent? One possible answer is found in californium 254, a nuclide first discovered in debris from the Mike test. Californium 254 decays by spontaneous fission, with a half life of about sixty days.

Multiple neutron capture is almost certainly the process by which heavy elements are synthesized in supernovae. Now that this process can be duplicated under controlled conditions on earth, a number of mysteries—new and old—may be nearing solution.

The Technical Side

Seminar, Massachusetts Institute of Technology, Cambridge, March 9:

"Use of an 800-MeV Proton Linac in Nuclear Physics Research" by D. E. Nagle, P-11.

Symposium on the Physics and Chemistry of Fission, IAEA, Salzburg, Austria, March 22-26:

"Simultaneous Velocity and Energy Measurements of Fission Fragments" by William E. Stein, P-2.

"Transition States at the Fission Barrier" by James J. Griffin, T-DO.

"Effects of Orbital Angular Momentum and Target Spin on Fission Anisotropy" by Judith Gursky and Robert B. Leachman, both P-12.

"Fission Mass Yield Studies" by G. P. Ford, J-11, and R. B. Leachman, P-12.

"Prompt Neutrons from Fission" by James Terrell, P-DOR.

"Symmetry of Neutron-Induced Pu^{239} Fission in Resonance Region" by G. A. Cowan, B. P. Bayhurst, R. J. Prestwood, J. S. Gilmore, and G. W. Knobeloch, all J-11.

"Investigation of Collective Nuclear Levels Near the Fission Threshold" by Harold C. Britt, P-DOR.

SHARE Meeting, Los Angeles, Calif., March 1-4:

"A Comparison of Some Least Squares Algorithms" by R. H. Moore, T-1.

Colloquium, Physics Dept., University of Colorado, Boulder, March 18:

"Air Fluorescence Excited by High Altitude Nuclear Explosions" by Herman Hoerlin, J-10.

Optical Society of America Meeting, Dallas, Texas, March 31:

"Air Fluorescence Excited by High Altitude Nuclear Explosions" by Herman Hoerlin, J-10. (Invited Paper)

American Nuclear Society Meeting, Santa Fe, March 19:

"Materials of Nuclear Power" by J. M. Taub, CMB-6.

Particle Accelerator Conference, Washington, D.C., March 10-12:

"Area Radiation Monitor System with Logarthmic Indication and Audio-Visual Warning" by Morris J. Engelke, H-1; Richard L. Henkel, P-9; Richard D. Hiebert, P-1; and H. K. Jennings and H. J. Lang, both P-9.

"A 40-Kilovolt, 125-Ampere Hard Tube Molulator for Accelerator Service" by Robert W. Freyman, P-1.

"Transverse Beam Blow-Up in a Standing Wave Linac Cavity" by Robert L. Gluckstern and Harold S. Butler, both P-11.

"Optimazation of Magnetic Lenses for Waveguide Portion of a Proton Linac" by William M. Visscher, T-DO.

"Beam Dynamical Calculations with Realistic Fields in a Drift Tube Linear Accelerator" by Marvin Rich, T-3.

"Design, Construction, and Testing of Rf Structures for a Proton Linear Accelerator" by Edward A. Knapp, P-11.

"Electron Analog Tests of Proton Linear Accelerator Structures" by John E. Brolley, Jr., P-DOR, C. Robert Emigh, GMX-11, and Donald W. Mueller, P-11.

"Numerical Studies of the Shapes of Drift Tubes and Linac Cavities" by Harry C. Hoyt, T-5.

"The Design of High-Intensity Muon Channels for a Meson Facility" by Harold S. Butler, P-11.

"Application of a Digital Computer to the Control and Monitoring of a Proton Linear Accelerator" by Thomas M. Putnam, Robert A. Jameson, and Thomas M. Schultheis, all P-11.

"High-Power Tests on a Cloverleaf Cavity" by Joseph R. Parker and James D. Doss, both P-11; Robert W. Freyman, P-1; Edward A. Knapp and W. J. Shlaer, both P-11.

"Resonantly Coupled Accelerating Structures for High-Current Proton Linacs" by James M. Potter, Bruce C. Knapp, Edward A. Knapp, and George J. Lucas, all P-11.

"A Tank-Coupling Scheme to Reduce Rf Amplifier Phase and Amplitude Tolerances in a Long Proton Linac" by George J. Lucas, Bruce C. Knapp, Edward A. Knapp and James M. Potter, all P-11.

"Electrical Behavior of Long Linac Tanks" by Darragh E. Nagle, P-11.

"Experimental Studies of Rd Phase and Amplitude Control for a Proton Linear Accelerator" by Thomas F. Turner and Robert A. Jameson, both P-11.

"Design of the Rf Phase and Amplitude Control System for a Proton Linear Accelerator" by Robert A. Jameson, P-11.

"An 805-Mc, 1-1/4-MW Amplifier for Accelerator Service" by Donald C. Hagerman, James D. Doss, both P-11; Robert W. Freyman, P-1; and Joseph R. Parker, P-11.

"Electrical Behavior of Long Linac Tanks and a New Tank-Coupling Scheme" by B. C. Knapp, E. A. Knapp, G. J. Lucas, D. E. Nagle and J. M. Potter, all P-11.

"Design of the Rf Phase and Amplitude Control System for a Proton Linear Accelerator" by R. A. Jameson and T. F. Turner, both P-11; and N. A. Lindsay, P-1.

Symposium on Personnel Dosimetry for Accidental High-Level Exposure to External and Internal Radiation, sponsored by IAEA and the World Health Organization, Vienna, Austria, March 8-12:

"Rapid Estimation of Fast Neutron Doses Following Radiation Exposure in Criticality Accidents. The $S^{32}(n,p)P^{32}$ Reaction in Body Hair" by D. F. Petersen, H-4.

Joint Session of New Mexico Industrial Photographers with Professional Photographers Association of New Mexico, Santa Fe, March 13:

"Public Relations Photography" by William H. Regan, PUB.

"Photography at Project Rover" by Robert PerLee, D-8.

"Color Printing at Los Alamos" by Frank D. May, D-8.

"Unusual Autoradiography" by Francis G. Berry, D-8.

"Classic Films and Film Makers" by Robert S. Harper, Jr., D-8.

Symposium of the London Zoological Society on the Evolution of the Cnidaria, London, England, March 3:

"Colony Development in Podocoryne Carnea as a Problem in Pattern Formation" by Maxwell H. Braverman, Carnegie Institute of Technology and Robert G. Schrandt, T-8. (Invited Paper)

Presentation to Mathematics Faculty and Graduate Students, Gonzaga University, Spokane, Washington, March 12:

"On Some Statistical Problems at LASL" by Aaron Goldman, T-1.

Physics Seminars: University of Washington, Feb. 26; Oregon State University, March 1, and University of Oregon, March 2:

"$He^3 + dt + 2p$ Reaction" by John H. Manley, DIR OFF.

Meeting of Oak Ridge Section of Society for Nondestructive Testing, Oak Ridge, Tenn., March 9:

"Basic Ultrasonics" by Paul D. Edwards, GMX-1.

American Physical Society Meeting, Kansas City, Mo., March 24-27:

"Location of the Conduction Band Minima in Diamond" by John L. Yarnell and John L. Warren, both P-2.

Talks at Saclay, Paris, France, March 15; University of Heidelberg, March 17; and University of Copenhagen, March 20:

"Nuclear Reaction Studies from Fluctuations in (α, p) Cross Sections" by R. B. Leachman, P-12.

WHAT'S DOING

LASL EVENING LECTURE: Dr. Kenneth S. Norris, UCLA, "Recent Advances in Porpoise Research." Lecture to include movies covering the behavior and training of porpoises. Open to the public, no charge.

Thursday, April 22, 8 p.m., Administration Building auditorium.

FILM SOCIETY: Civic Auditorium. Films shown 7 and 9:15 p.m. Admission by season ticket or 90 cents single admission.

Wednesday, April 21, "The Organizer," 1964 Italian drama, 126 minutes.

SWIMMERS CLUB OF LOS ALAMOS: Swims every Sunday, 7 to 9 p.m., high school pool. Membership open to all interested adults.

LOS ALAMOS HIGH SCHOOL POOL: Schedule for public swimming. Adults 35 cents, students 15 cents.

Saturday	1 p.m. to 5 p.m.
Sunday	1 p.m. to 5 p.m.
Monday	7 p.m. to 9 p.m.
Tuesday	7 p.m. to 9 p.m.

SWIMMING CLASSES: sponsored by Red Cross for members of the Calorie Counters and all pre-natal and post-natal women. Free. Meets every Saturday, noon to 1 p.m., High School pool. Phone 2-4094 for further information.

NEW HIRES

David Richard Copenhagen, Oakland, Calif., P-11.

Jerilyne Sue Stephenson, Espanola, N.M., GMX-3 (Rehire).

John R. Hartman, Albuquerque, N.M., CMB-7.

Elsie R. Herrera, Espanola, N.M., GMX-3.

John J. Ross, Columbus, Ohio, K-1.

Guy E. Barasch, Baltimore, Md., J-10 (Rehire).

Earl Mark Dolnick, Urbana, Ill., P-16.

Eli O. Fraser, Santa Fe, N.M., CMB-3.

Mary C. Bryant, Los Alamos, Bus. Off., (Casual-Rehire).

Charles Dawson Frank, Denison, Texas, ENG-3 (Rehire).

Phyllis Arline Lemons, Los Alamos, GMX-7 (Rehire).

Eleanor L. Flanders, Lowell, Mass., GMX-3.

Jack N. Halliday, Los Angeles, Calif., SP-1.

Alford J. Fuchs, Santa Fe., N.M., GMX-3.

Geraldine F. Michel, Los Alamos, SP-1.

Victor T. Wit, Amarillo, Texas, ENG-2.

Richard W. Andrae, San Diego, Calif., N-7.

Donald J. Dudziak, Alden, N.Y., K-1.

Roy L. Beacham, Santa Fe, N.M., GMX-3.

Danny Garland Gill, Los Alamos, SP-3 (Short Term).

Lawrence L. Sprous, Alamosa, Colo., ENG-3.

Carole Lou Whitmore, Los Alamos, J-15.

NASA CHIEF PRAISES LAB'S A-ROCKET WORK

"When we are ready to go to the planets, nuclear power will be essential," James E. Webb, head of the National Aeronautics and Space Administration, said last month after a tour of Los Alamos.

Here on his first official visit, the nation's chief space administrator said Los Alamos is paving the way for nuclear rocket propulsion in space. He said that the U. S. probably can reach the moon with chemical rockets, but that any effort to reach the planets will require the use of nuclear powered rockets such as are now being developed under Project Rover, in which LASL plays a leading role.

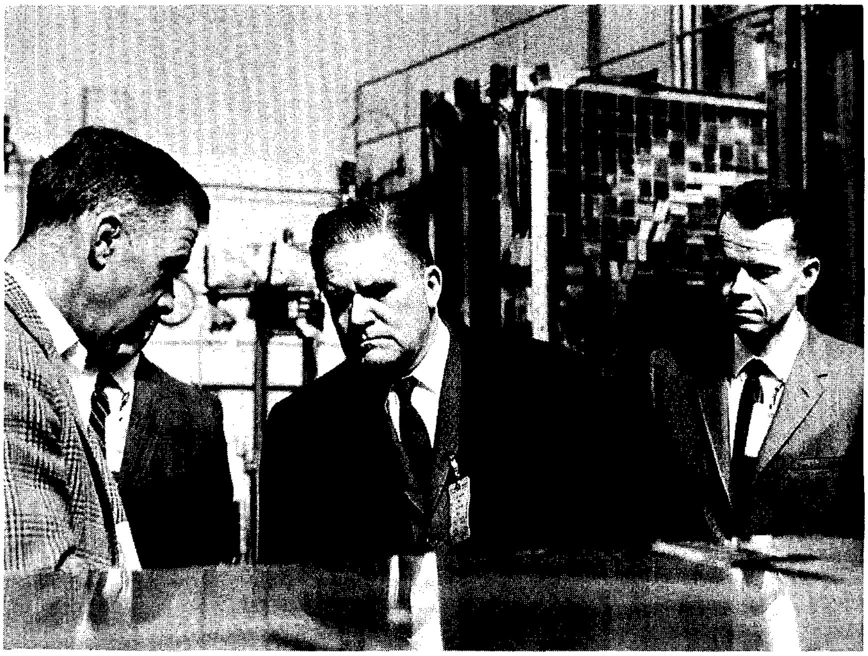
Webb praised the work of Los Alamos, Sandia and White Sands in furthering the nation's progress in space. He said that he could not be sure the U. S. would be first to land a man on the moon, but that this country was still very much in the race despite recent and spectacular Russian demonstrations.

In a nationwide TV broadcast, Webb said the Saturn 5 moon rocket now being developed was "very much larger" than anything the Russians have. He compared the Saturn 5's 260,000 pounds of payload in orbit with the largest known Russian rocket which has a payload of about 15,000 pounds.

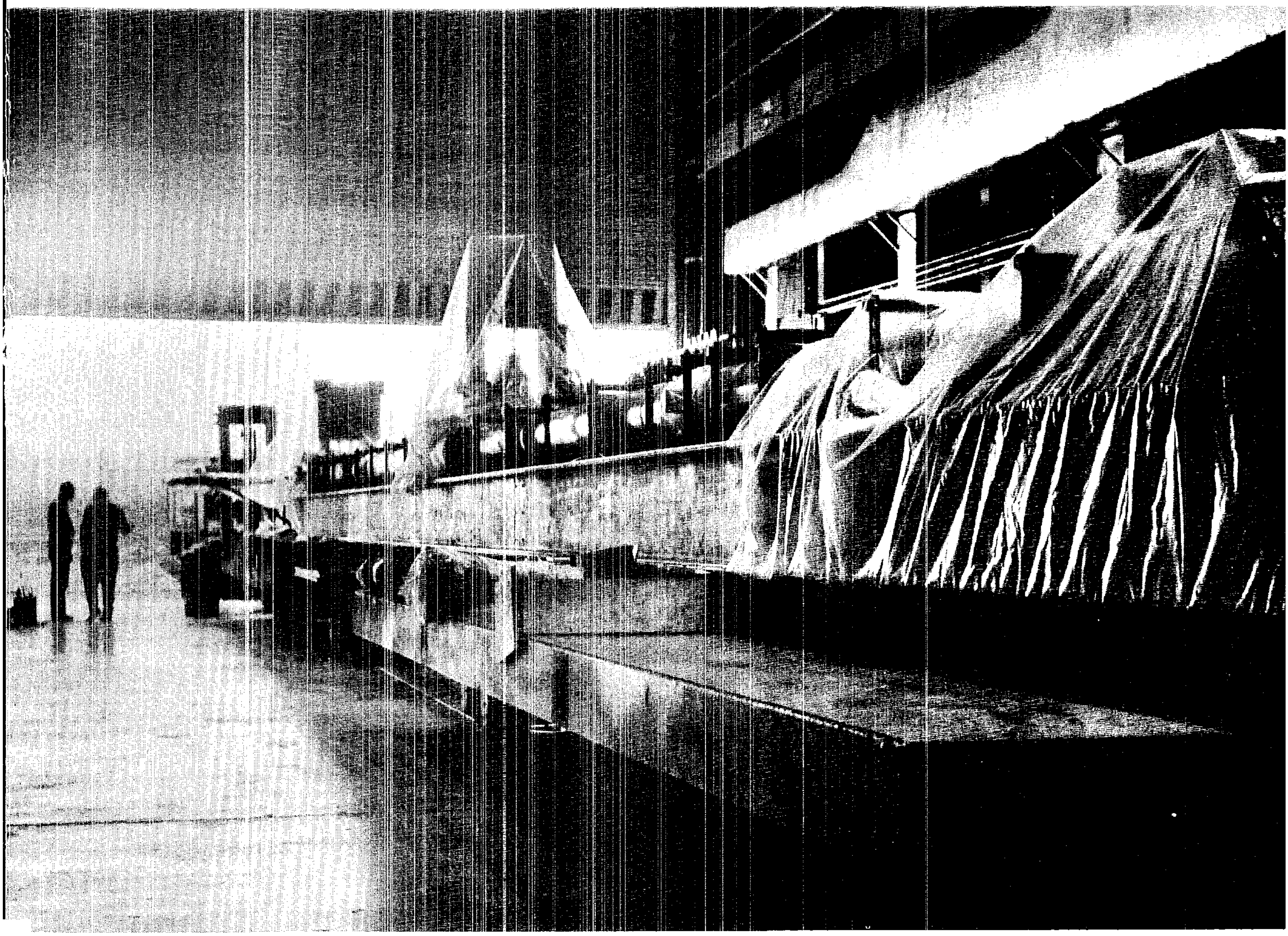
He pointed out that in developing large rockets burning a hydrogen and oxygen mixture, NASA is gaining valuable experience in handling large quantities of liquid hydrogen which will be useful when Rover reaches the flight stage, since the Kiwi and Phoebus type nuclear rocket engines both use liquid hydrogen. He also said that nuclear rockets might be needed sooner than expected if shuttle flights to and from the moon were required.

Webb came to Los Alamos March 19 for a hurried tour of the facilities at Pajarito site, where nuclear components of the Kiwi and Phoebus reactors are studied. He was then given a briefing by Laboratory Director N. E. Bradbury, Associate Director Raemer Schreiber, N Division Leader Rod Spence, Alternate Division Leader Frank Durham, and others. Following a luncheon, he left for Albuquerque to preside over a news conference and to give a talk at a meeting of engineers.

Webb made a point of praising Senator Clinton P. Anderson and Congressman Thomas G. Morris for their "inspiration, strength, wise counsel and support" for the space program.

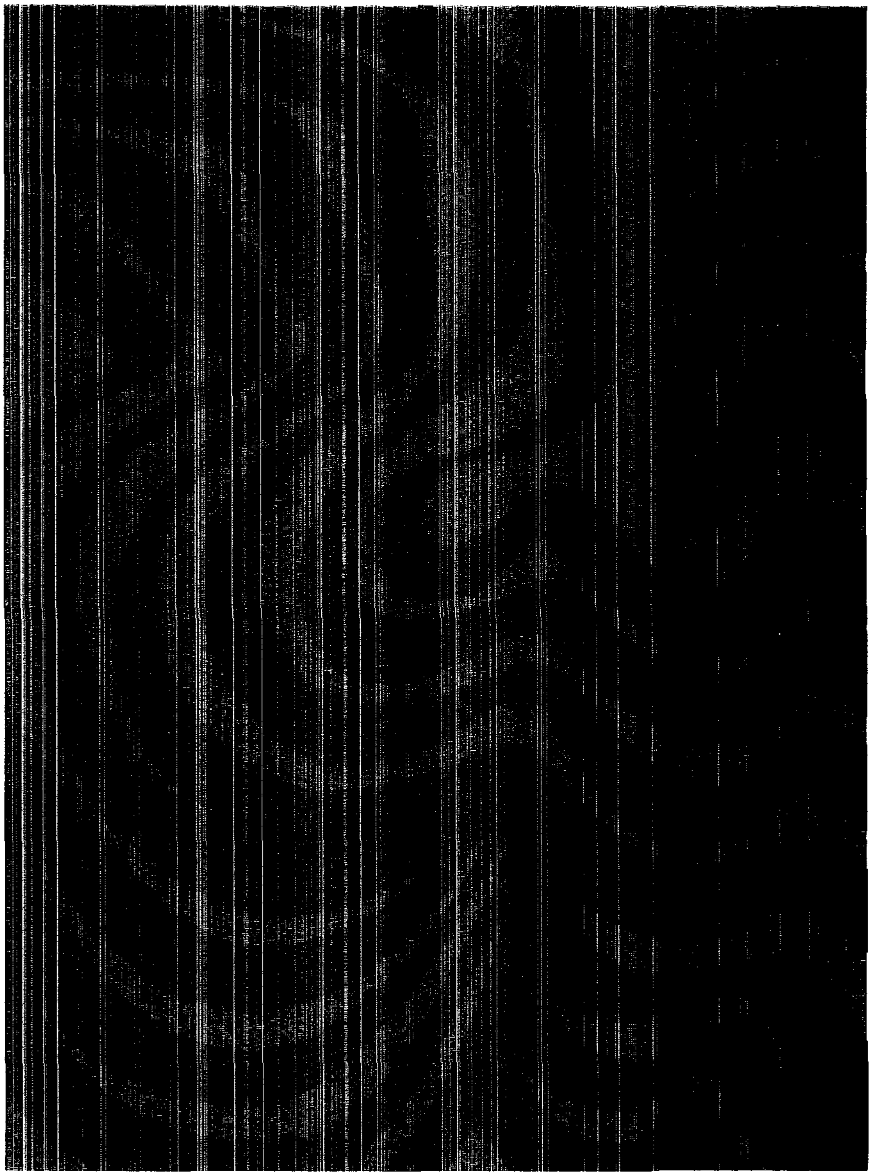


James E. Webb (center), NASA's chief administrator, looks over a part of a Phoebus-type reactor during a quick tour of Pajarito Site facilities March 19. John Orndoff, alternate N-2 group leader, and Frank Durham, alternate N division leader, explain the work.



A Long Load For the J & W

A 100-foot-long section of a new heat exchanger to be used in connection with the testing of LASL Phoebus reactors at the Nuclear Rocket Development Station in Nevada leaves the R-MAD Building after assembly, bound for Test Cell C. Shown suspended between two flat cars of the so-called "Jackass & Western R.R." in this photograph taken last month, the long device is the first of eight such sections to be installed at the test cell this year. The exchanger will use hot water to gasify liquid hydrogen which will in turn drive the coolant/propellant turbopump for the advanced nuclear rocket reactors. The first section is currently undergoing a series of tests which will allow LASL personnel to learn how to handle the hydrogen under various reactor demands. The exchanger is being built by ACF Industries, Albuquerque, and assembled at NRDS. Photograph by W. L. Headdy.



Interpretation by William Thonson

Henry E. Motz
3187 Woodland
Los Alamos, New Mexico